Virtual National Laboratory for Heavy Ion Fusion

January/February 2003

HIF News

LBNL-PUB-844-03-01/02

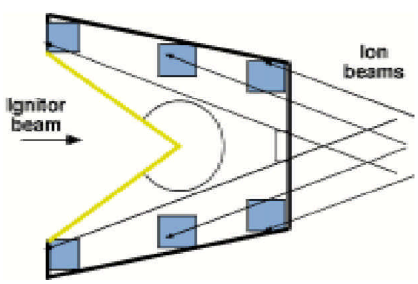
Fast Ignition Targets for HIF

Fast ignition promises high target gain with reduced driver energy and peak power. To quantify the benefits for an HIF driver, we estimated the beam energy and power needed to compress fuel with heavy ions for fast ignition. The short-pulse, ignitor beam could be either a laser or a heavy-ion beam.

We considered two capsules and two hohlraums. One capsule, driven at 150 eV, reached an average density of 175 g/cc in 1-d calculations. Based on Atzeni's formula (S. Atzeni, Phys of Plasmas, 6, 3316-3326, 1999), 50 kJ of ignitor energy deposited would be needed (i.e. a 150 kJ short pulse laser, assuming 33% coupling efficiency). The second capsule, driven at 120 eV, reached an average density of 80 g/cc, and required 200 kJ of ignitor energy deposited.

The first hohlraum, based on the hybrid target, allows a large beam spot (~ 5 mm radius). A cone focus was added to the side of the target for the ignitor beam. Simple scaling estimates suggest this target would require 2.9 MJ of energy and 170 TW peak power for the 150 eV capsule and 2.3 MJ of energy and 85 TW peak power for the 120 eV capsule.

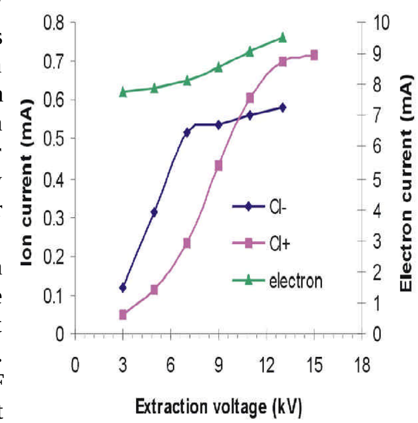
The second hohlraum provides a one-sided geometry with the ion beams hitting converters located at the zeros of the third Legendre polynomial. The ignitor beam would enter from the opposite side via a cone focus (shown in the figure). The beam spot size was assumed to have a 2 mm radius. Simple scaling estimates suggest this target would require 2.7 MJ and 160 TW for the 150 eV capsule and 1.9 MJ and 70 TW for the 120 eV capsule.



~ Debbie Callahan, Mark Herrmann, and Max Tabak

Negative Ion Beam Possibility

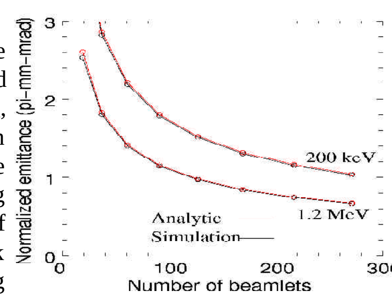
Negative ion drivers have recently attracted interest after a PPPL study found that modest extrapolations of existing technologies might result in a viable alternative to positive ions. Unlike positive ions, negative ion beams will not collect electrons from surfaces they pass, which changes their focusing characteristics, and negative ions can readily be photodetached to neutrals near the target chamber. Although they will be ionized in crossing the chamber medium, starting as neutrals should reduce the beam space-charge-expansion. The halogens iodine and bromine have the most appropriate masses for the HIF, but chlorine is more tractable for testing in an unheated source. PPPL recently joined LBNL and HIF-VNL in an experiment at LBNL using Cl in an RF ion source. Without introducing any cesium a Cl^- current density of 45 mA/cm^2 was obtained under the same conditions that gave 53 mA/cm^2 of positive chlorine, suggesting the presence of nearly as many negative ions as positive ions in the extraction plane plasma. The e/Cl^- ratio in the beam was as low as 7, much lower than the ratio of their mobilities, also suggesting few electrons in the near-extractor plasma. The negative ion spectrum was 99.5% Cl^-, with only 0.5% Cl_2^-, and negligible impurities. The Cl^- current scaled linearly with RF power. If this scaling holds at higher RF powers, it should yield current densities of 100 mA/cm^2, sufficient for present injector concepts, as above.*~ Larry Grisham*



Merging Multi-Beamlet Injector

For future heavy ion drivers, which can have of order of 100 beams, the injector must produce high-brightness beams and be compact. With a traditional, monolithic hot-plate source, design constraints force the current density to be inversely proportional to the current, limiting the achievable brightness for high current beams (> 0.5 A).

The merging multiple beamlet injector avoids the constraints by using many small beamlets, each with low current (~5 mA) and high current density (~100 mA/cm^2). Other advantages include a smaller transverse footprint, more control over the beam shape, and more flexibility in the ion source choice. Since there are many beamlets, the merged beam will be robust to beamlet errors.



Particle simulations using the WARP code have led to a solid understanding of the merging, and the emittance growth inherent in the process. The final emittance has a strong dependence on the number of beamlets and a weak dependence on the merging energy (over a reasonable range ~1 MeV). A procedure was developed to produce a design that gives an optimal emittance for a given set of basic parameters. We believe we can achieve an acceptably low emittance with a reasonable number of beamlets (of order of 100-150).

At LLNL, with LBNL, we are developing scaled experiments to test the concepts. We believe that the multi-beamlet injector will offer a substantial improvement over the traditional approach for a multi-beam HIF driver. *~ Dave Grote*

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This work was performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48 and by Lawrence Berkeley National Laboratory under contract No. DE-AC03-76SF00098 (LBNL), and by Princeton Plasma Physics Laboratory performed under the auspices of the U.S. Department of Energy under contract No.DE-AC02-76CH-O3073.